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# CHANGE IN TRANSMISSION COEFFICIENT OF SCREEN GLASS MELTING IN A FLAME TANK FURNACE

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The practical experience of modifying the transmission coefficient of glass for electron monitor screens in an operating tank furnace is considered. Calculation formulas are proposed that can be used to minimize the period of substandard product yield.

It is generally known that light transmission and the contrast range of glass are the most important parameters responsible for the image quality on screens of electronic equipment. Since luminophores are deposited on the inner surface of the screen, the light radiated by them arrives at the observer after passing through the glass layer and is reduced by the transmission coefficient value $\tau$, whereas the degree of contrast depends on $\tau^2$.

For many years kinescope screens at the Ékranas Company were produced only from dark glass with a transmission coefficient equal to $48.5 \pm 0.5\%$. However, the world practice currently uses kinescopes with light glass as well, and the light transmission of screen glass may vary from 42 to 85%. This is related to the expanding product range of colored electrovacuum devices using increasingly flat screens. The increase in light transmission makes it possible to decrease the difference in this parameter in the middle and at the edges of the screen caused by the different glass thickness in these areas. However, it is necessary to ensure the required degree of contrast in the image. The industrial production of kinescopes normally uses glass with light transmission of 46 – 57% and thickness 10.16 mm. With light transmission growing to 57 – 58% or more, the colored image contrast needs to be improved by applying plastic or other type of coating to the screen.

To meet the consumer requirements and market trends, the Ékranas Company in the production of flat color screens within a short time had to modify glass transmission while ensuring the required degree of contrast and other properties of glass.

The present study analyzes the changing light transmission of glass being melted in an operating furnace and proposes a method for accelerating this change.

Recently the Ékranas Company consecutively carried out four operations modifying the light transmission of glass: from dark (transmission coefficient $48.5 \pm 0.5\%$) to light ($56.5 \pm 0.5\%$) and back from light to dark glass with the same transmission coefficient. In doing so, the following main problems had to be solved:

– identify the lag time of the tank furnace;

– determine the quantity of colorants to be introduced to melt light-colored glass while preserving its color coordinates;

– calculate the optimum composition and melting duration for a corrective batch for the purpose of reducing the amount of substandard product in the transition period;

– provided the stability of TCLE and density of glass.

In order to achieve a preset light transmission level in glass and its optimum tinting to provide for the optimum transmission of the luminosity of the luminophores and preserve the color coordinates within the required limits, it was necessary to develop a method for correcting the batch composition taking into account the composition of cullet introduced.

The Ékranas Company uses nickel and cobalt oxides to impart a neutral tint to the color kinescope screen. It is known that the introduction of nickel oxide in glass produces an absorption band in the range of 420 – 430 nm and the introduction of cobalt oxide causes a wide absorption band in the range of 550 – 650 nm. The combination of certain quantities of these colorants makes it possible to achieve homogeneous absorption in the total visible spectrum range (400 – 700 nm). Screen glass always contains more nickel oxide, imparting a gray color to the glass, than cobalt oxide, which imparts a blue tint. However, the content of nickel and cobalt oxides introduced into the batch to improve the contrast range on the screen should ensure compliance with requirements on light transmission in glass.

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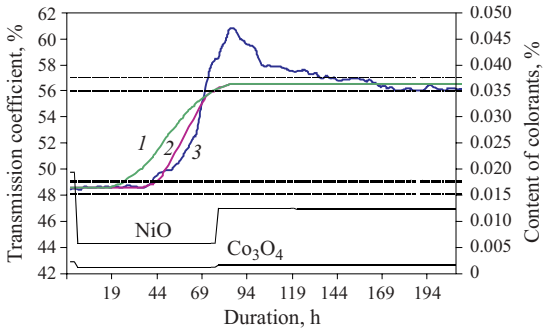


**Fig. 1.** Estimated, for a furnace lag of 18 h (*1*) and 36 h (*2*), and experimental (*3*) kinetic curves of changing transmission coefficient in the transition from dark to light glass.

When the Ékranas Company used to produce dark electrovacuum glass with a transmission coefficient of 48.5 ± 0.5%, the quantities of the colorants were known: 0.01930% NiO and 0.00218% $Co_3O_4$.

Since the light transmission of glass melted in a new tank furnace changed for the first time, the quantities of nickel and cobalt oxides required for light glass were unknown and were taken based on the production experience of the Techneglass Company: 0.01180% NiO and 0.00160% $Co_3O_4$. Precise proportioning of nickel and cobalt oxides has become possible after the reconstruction of the batch-preparation line equipped with cullet proportioners.

The charging time for a special batch intended to achieve the required quantities of the colorant oxides in the total melt was calculated based on the following formula:

$$C = 1 - e^{-\frac{t}{V\varepsilon/P - T}}, \qquad (1)$$

where $C$ is the content, in fractional units, of the special corrective batch (taking into account the quantity of cullet that has to be mixed with initial melt $(1 - C)$ and provides for the required quantity of colorant oxide after modification of the transmission coefficient of glass; $V$ is the quantity of glass melt in the furnace, tons; ε is the furnace efficiency; $P$ is the furnace output, tons/h; $T$ is the furnace time lag, h; $t$ is the time of feeding the special batch into the furnace, h.

It can be seen that the furnace time lag depends on its parameters. There were no experimental data on the time lag for the new flame furnace of the Ékranas Company; therefore, in calculating the special batch composition and the time of its charging into the furnace, the time lag was taken to be 18 h. It should be noted that the special batch contained 30% cullet of dark electrovacuum glass.

Calculations carried out in accordance with Eq. (1) demonstrated that in using a batch without colorants and with 30% dark glass cullet, the content of $Co_3O_4$ in the new glass composition changed to the required quantity (0.00160%) in 38 h and the content of NiO changed in 64.4 h. Calculation of the special batch composition established that by feeding it into the furnace together with glass cullet for 64 h, the quantity of $Co_3O_4$ should be reduced to one-third compared to the $Co_3O_4$ content in the batch for dark glass (to 0.00069%), and NiO altogether should not be introduced into the special batch.

During the first transition from dark to light glass the transmission coefficient was periodically measured after every 2 h for the monochromatic radiation wave of 550 nm. The following formula was used to convert light transmission from experimental glass thickness to the transmission of a plate of 10.16 mm:

$$\tau_{10.16} = (1 - \rho)^2 \, e^{\ln\left(\frac{\tau}{(1-\rho)^2}\right)\frac{10.16}{d}}, \qquad (2)$$

where ρ is the reflection index (for tested electrovacuum glass ρ = 1.5385); $d$ is the glass thickness at the point of determining light transmission, mm; τ is the measured value of light transmission, %.

The analysis of the first transition from dark to light glass (Fig. 1) indicated that the time lag of the tank furnace is significantly longer than the value initially accepted, i.e., 36 h against 18 h.

On the other hand, after 76 h of using the special batch, the light transmission in glass amounted to 58.5% instead of the expected 56.5% and kept increasing, i.e., the maximum permissible value for the light transmission of glass was exceeded, while the content of the colorant oxides was insufficient.

Based on the data obtained, the following correctives were accepted for calculations: the lag of the tank furnace was taken equal to 36 h and the content of the colorants in light glass was raised to 0.01220 % NiO and to 0.00164% $Co_3O_4$. The calculations indicated that achieving this quantity of NiO in light glass occurs upon mixing 47.45% melt of dark glass and 52.55% melt obtained from a batch without colorant oxides and 30% dark glass cullet. Calculations according to Eq. (1) show that the change in NiO quantity should occur within 46 h.

The correction of light transmission variation was started 76 h after the beginning of using the special batch. In order to change from excessively light glass to light glass, the total required content of nickel and cobalt oxides in the batch with cullet was calculated and found equal to 0.012561% NiO and 0.001676% $Co_3O_4$. The second batch of the modified composition was charged into the furnace for 46 h. After 122 h from the beginning of charging, the batch composition was modified to have the total content of the colorant oxides at the level of 0.01220 % NiO and 0.00164 % $Co_3O_4$.

It can be seen from Fig. 1 that the time lag of the tank furnace which, in turn, depends on the furnace efficiency and the convection flows in the melt, has a great effect on the variation rate of light transmission in glass.

During the variation of the light transmission of glass, the transmission coefficient was determined simultaneously

with chromaticity coordinates, the TCLE, and the density of glass.

The chromaticity coordinates of glass for color screens were determined according to the colorimetric system recommended by the International Lighting Commission using a D93 color source (light temperature 9300 K, chromaticity coordinates: $x = 0.281$, $y = 0.310$).

The analysis of the chromaticity coordinates indicates that simultaneously with a sharp increase in light transmission for 74 – 98 h after the start of changing the light transmission of glass, the color coordinates remained outside the small hexagon bounds and returned to that hexagon simultaneously with the stabilization of light transmission values.

The values of the TCLE and density of glass during the modification of light transmission fluctuated insignificantly: TCLE $(99.0 – 99.3) \times 10^{-7}$ K$^{-1}$, density 2760 – 2761 kg/m$^3$; the quantity of glass defects changed insignificantly as well.

With the reverse change in glass transmission, i.e., in the transition from light to dark glass, the true time lag of the new flame tank furnace for a constant output is 36 h.

Based on the data obtained during the first transition ($T = 36$ h, $t = 46$ h) it was calculated using formula (1) that the required quantities of the colorants for dark glass would be obtained in mixing 47.31% light glass melt with 52.69% melt of the batch with light glass cullet. This was taken into account to calculate the quantities of NiO and $Co_3O_4$ in the batch with cullet, which amounted to 0.025676 and 0.002665%, respectively.

During the required time (46 h) the light transmission of glass was modified using the special batch; then the batch composition was modified to have the total content of the colorant oxides equal to 0.01930% NiO and 0.00218 % $Co_3O_4$. However, similarly to the first modification of the light transmission of glass, the experimental duration of the transition was approximately 1.5 times longer than the estimated time. In the transition from dark to light glass the chromaticity coordinates changed steadily, simultaneously with changing light transmission; however, they did not leave the limits of the chromaticity hexagon. The kinetics of light transmission variation in the transition from light to dark glass is represented in Fig. 2*a*.

In subsequent modifications of light transmission, in order to accelerate the transition from light to dark glass, the glass melt output was increased by approximately 10% and the furnace lag was decreased to 28 h.

The best results in modifying the light transmission of glass were obtained in the transition from light glass with a light transmission of $56.6 \pm 0.5$ % to dark glass with a light transmission of $48.5 \pm 0.5$%, with constant and higher furnace efficiency (Fig. 2*b*).

In this case the experimental lag of the furnace amounted to 26 h. The estimated and experimental kinetic curves of light transmission show good agreement; the period in which

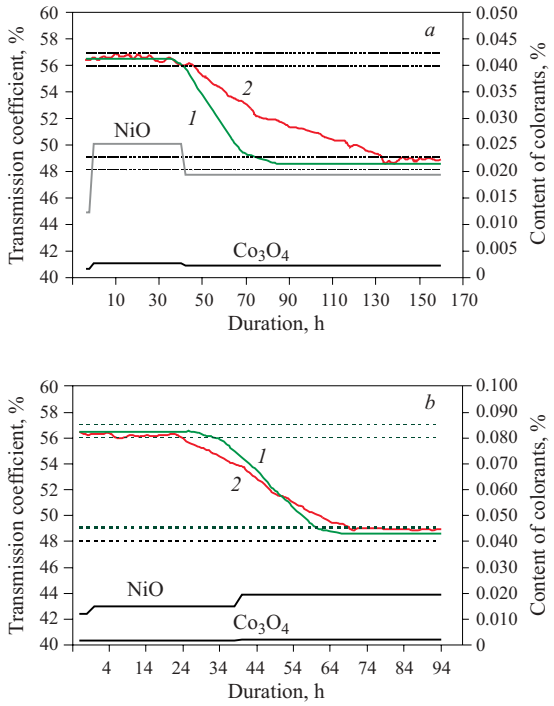


**Fig. 2.** Estimated (*1*) and experimental (*2*) curves of changing light transmission in the second (*a*) and the fourth (*b*) transition from light to dark glass.

glass unsuitable for screens was produced lasted 46 h (compared to 92 h in the first change of light transmission); the chromaticity coordinates during the entire transition period changed insignificantly and did not leave the limits of the small chromaticity hexagon.

Thus, the ratios and quantities of colorant cobalt and iron oxides required for the production of light electrovacuum glass for color kinescope screens with a transmission coefficient $56.6 \pm 0.5$% have been determined (0.00164% $Co_3O_4$ and 0.01220% NiO). The colorant oxides need to be precisely proportioned by weighing units taking into account the cullet used.

The time lag of the tank furnace at the Ékranas Company was experimentally determined (36 and 28 h) depending on its output.

It is demonstrated that upon determining the precise furnace lag values, it is possible to calculate the required period for using special batches in the transition from dark electrovacuum glass to light glass and vice versa, which makes it possible to minimize the period of melting glass that is unsuitable for making screens.

It is observed that with an appropriate organization of the process of changing the light transmission of glass the chromaticity coordinates do not exceed admissible limits, and the TCLE and density of glass vary insignificantly.